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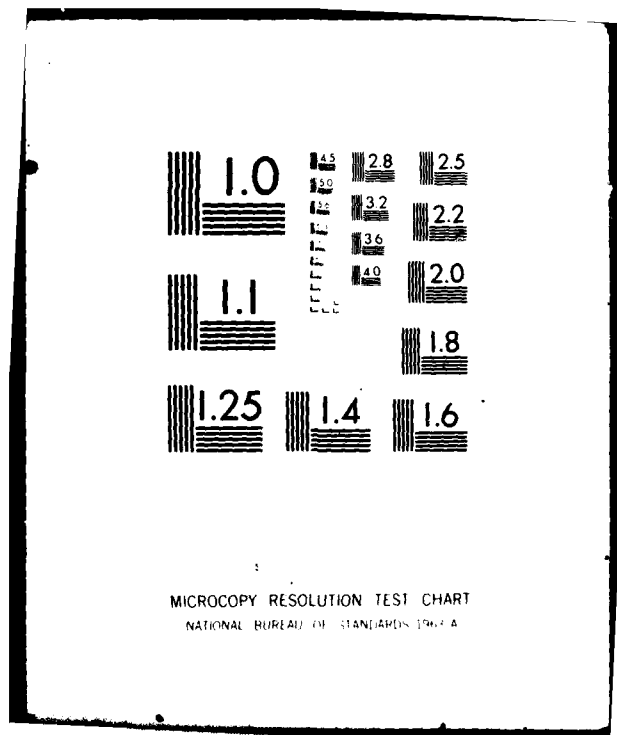
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THE TOXICITY AND BIODEGRADABILITY  
OF HYDRAZINE WASTEWATERS TREATED  
WITH UV-CHLORINOLYSIS

LEVEL II

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## 20. ABSTRACT (Concluded)

Stock culture organisms reared on milk solids and trickling filter slimes from a full-scale secondary plant were investigated using both standard substrates and the contrived wastewater. Biodegradation data showed that substrate inhibition does not occur with either the stock culture organisms or the trickling filter slimes. The data confirmed that the contrived wastewater does not inhibit those organisms tested and showed, in fact, that the wastewater itself can be recovered as oxygen uptake. The wastewater exerted an oxygen demand of approximately 150 mg/l in the presence of 875 mg/l volatile trickling filter solids.

Pretreatment with a bench-scale strong base ion exchange column had no effect on the uptake of standard substrate by trickling filter organisms significantly reduced the toxicity to the stock culture organisms.

Activated carbon pretreatment data suggested that no chlorinated hydrocarbons or incomplete oxidation products were formed during the UV-chlorinolysis process. Cumulative oxygen uptakes for these samples were very comparable in both the toxicity and biodegradation protocols. Stock culture organisms responded with a three-fold increase in cumulative oxygen uptake, whereas the filter organisms showed no significant change in degradation.

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## PREFACE

This report was prepared by Captains Anthony M. Wachinski and Jay A. Farmwald based on in-house research conducted at the Civil and Environmental Engineering Development Office (CEEDO), Detachment 1, Headquarters, Armament Development and Test Center (HQ ADTC), Tyndall Air Force Base (AFB), Florida, from December 1978 to February 1979. CEEDO became the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall AFB, Florida 32403 on 1 February 1979.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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# TABLE OF CONTENTS

Section	Title	Page
I.	INTRODUCTION.....	1
II.	METHODS AND MATERIALS.....	2
	1. Waste Characterization.....	2
	a. General.....	2
	b. Chlorination End Products.....	2
	c. Incomplete Oxidation Products...	3
	2. Warburg Technique.....	3
	3. Cultures.....	5
	a. Stock Culture.....	5
	b. Trickling Filter Organisms.....	5
	4. Experimental Work .....	9
	a. General.....	9
	b. Pretreatment.....	10
	c. Warburg.....	10
	d. Stock Culture Studies.....	11
	e. Filter Organism Studies.....	11
III.	RESULTS AND DISCUSSION.....	14
	1. Toxicity.....	14
	a. Stock Culture Organisms.....	14
	b. Trickling Filter Organisms.....	14
	c. Pretreatment.....	17
	(1) Carbon.....	17
	(2) Ion Exchange.....	17

# TABLE OF CONTENTS (Concluded)

Section	Title	Page
	2. Biodegradability.....	21
	a. Stock Culture Organisms.....	21
	b. Trickling Filter Organisms.....	25
IV.	SUMMARY.....	27
V.	CONCLUSIONS.....	30
	REFERENCES.....	31
APPENDIX		
A	STOCK CULTURE DUPLICATE FLASK DATA.....	33
B	TRICKLING FILTER DUPLICATE FLASK DATA.....	44

# LIST OF FIGURES

Figure	Title	Page
1	The Effect of IITRI Wastewater on the Respiration of Stock Culture Organisms.....	15
2	The Effect of IITRI Wastewater on the Respiration of Trickling Filter Organisms.....	16
3	The Effect of Activated Carbon Pretreatment on the Toxicity of IITRI Wastewater to Stock Culture Organisms.....	18
4	The Effect of Activated Carbon Pretreatment on the Toxicity of IITRI Wastewater to Trickling Filter Organisms.....	19
5	The Effect of Ion Exchange Pretreatment on the Toxicity of IITRI Wastewater to Stock Culture Organisms.....	20
6	The Effect of Ion Exchange Pretreatment without pH Adjustment on the Toxicity of IITRI Wastewater to Stock Culture Organisms.....	22
7	The Effect of Ion Exchange Pretreatment on the Toxicity of IITRI Wastewater to Trickling Filter Organisms.....	23
8	Biodegradability of IITRI Wastewaters by Stock Culture Organisms.....	24
9	Biodegradability of IITRI Wastewaters by Trickling Filter Organisms.....	26

# LIST OF TABLES

Table	Title	Page
1	Analysis of RMA Treated Wastewater.....	4
2	Products Expected from the Incomplete Chlorination of Hydrazine Fuels.....	5
3	Inorganic Salts Used for the Growth of Stock Culture.....	6
4	Phosphate Buffer Composition.....	8
5	Buffer/Inorganic Salts Medium.....	9
6	Stock Culture Flask Matrix.....	12
7	Filter Organism Flask Matrix.....	13
8	Sixty-Hour Oxygen Uptake Summary.....	27

## SECTION I

### INTRODUCTION

In August 1978, IIT Research Institute (IITRI) was tasked with developing design data for a system to treat hydrazine-laden wastewater generated by the Air Force Logistics Command (AFLC) Blend Facility at the Rocky Mountain Arsenal (RMA). The Blend Facility currently discharges 1000 to 2000 gallons of wastewater a day to a holding pond; there it is treated with calcium hypochlorite and ultimately discharged to a nearby lake. Concern over neat hydrazine (HZ), unsymmetrical dimethylhydrazine (UDMH), and dimethyl nitrosamine (DMNA) in the holding pond effluent prompted the Colorado Department of Health, Water Pollution Control Commission, to rule the present treatment system unsatisfactory. A system proposed by IITRI would incorporate ultraviolet (UV) catalyzed chlorine to treat the wastewater. Residual chlorine would be neutralized with sodium thiosulfate, the effluent being discharged to the RMA trickling filter plant and ultimately to a receiving stream.

On 31 October 1978, IITRI requested that the Air Force Engineering and Services Center, Division of Environics (AFESC/RDV) evaluate the toxicity of the chlorinated wastewater and comment on the possible effects of the effluent on the RMA trickling filter. The approach formulated by RDV involved classic Warburg Respirometer techniques coupled with an evaluation of ion exchange and activated carbon as pretreatment alternatives. This report summarizes data from these studies and their interpretation.

## SECTION II

### METHODS AND MATERIALS

#### 1. WASTE CHARACTERIZATION

a. General. The wastewater obtained from IITRI originally contained 500 parts per million (ppm) HZ, 500 ppm UDMH, 100 ppm DMNA, and 500 ppm monomethylhydrazine (MMH). This synthetic wastewater had been batch treated in a 12-liter glass reactor at a radiation level of 0.9 watt/liter. The experiment was performed at pH 5. Chlorine was added to the reactor at a low flow rate to allow pH control to  $\pm 0.1$  pH unit. The UV light was placed in the reactor from the start of the experiment. IITRI had reported that the MMH, UDMH, and HZ reacted rapidly with the chlorine, keeping residual chlorine below detectable levels in the reactor throughout the first phase of the experiment. When these three compounds were consumed, the chlorine concentration began to increase. The chlorine concentration was then brought to 500 ppm and held at that level for several hours. After the run the pH was adjusted to 7, residual chlorine removed with sodium thiosulfate, and capillary gas chromatography (Reference 1) analyses performed to verify the complete oxidation of the hydrazines and DMNA.

Using procedures outlined in Standard Methods (Reference 2), the treated wastewater was characterized in this laboratory as outlined in Table 1. Chemical Oxygen Demand (COD) analyses were performed, but results were erratic due to high chloride and sulfate concentrations. The COD was estimated to be 450 milligrams per liter (mg/l).

b. Chlorination End Products. The stoichiometry associated with the chlorinolysis of HZ, MMH, UDMH and NDMA predicts

methanol, nitrogen gas, and hydrochloric acid as the only reaction products. However, it is known that several alternative mechanisms may proceed under certain conditions which involve more than one electron transfer and can lead to the formation of ammonia and methane. These compounds, in the presence of excess chlorine, could lead to the formation of certain chlorinated hydrocarbons and amines, including  $\text{CH}_3\text{Cl}$ ,  $\text{CH}_2\text{Cl}_2$ ,  $\text{CHCl}_3$ ,  $\text{CCl}_4$ ,  $\text{NH}_2\text{Cl}$ ,  $\text{NHCl}_2$ , and  $\text{NCl}_3$  (the most undesirable since it is explosive). The other compounds in the treated effluent prompted IITRI to conduct capillary gas chromatography (GC) analyses (Reference 1) on the wastewater. All of the compounds in question were found to be below detectable limits.

c. Incomplete Oxidation Products. Recent gas chromatography mass spectrometry (GC-MS)\* work on the hydrazine fuels in our Environmental Sciences Branch has shown that the products associated with the incomplete chlorination of these fuels are quite numerous. A summary of those compounds identified to date is presented in Table 2.

None of these compounds were detected in the treated IITRI sample, using GC-MS, indicating that the oxidation had gone to completion.

## 2. WARBURG TECHNIQUE

The Warburg used in this study was a Precision Scientific rotary apparatus with 18 manometer stations. A shaking rate of 130 strokes per minute was used with a shaking stroke of four centimeters. The constant-temperature bath was maintained at

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\*Finnigan 3200 coupled to a System 150 data system.

25°C. Manometers were open-end U-tubes calibrated from 0 to 30 cm in one-millimeter (mm) increments. Unity oil, specific gravity 1.000 was used as manometer fluid. Each manometer was equipped with an adjustable fluid reservoir for maintaining the system at constant volume. Respirometer flasks were conical, borosilicate glass-vessels with side-arm and centerwell. Each flask-manometer couple was calibrated using a Gilmont® calibrator, as described by Yamaguchi (Reference 3). All experiments were conducted with 0.2 ml of 10 percent KOH in the center well. Folded 2 cm<sup>2</sup> strips of Whatman #1 filter paper were also placed in the center wells to enhance CO<sub>2</sub> absorption. The other flask components were as described in subsections 4d and 4e.

TABLE 1. ANALYSIS OF RMA TREATED WASTEWATER

<u>Parameter</u>	<u>Concentration (mg/l)</u>
Total Solids (TS)	10,790
Total Volatile Solids (TVS)	2,670
Total Suspended Solids (TSS)	10
Total Kjeldahl Nitrogen (TKN)	4.5
Ammonia Nitrogen (NH <sub>3</sub> -N)	9
Sulfates (SO <sub>4</sub> )	58
Chlorides (Cl)	5,250
Total Alkalinity (MO)	10 (as CaCO <sub>3</sub> )
pH	6.8

TABLE 2. PRODUCTS EXPECTED FROM THE INCOMPLETE  
CHLORINATION OF HYDRAZINE FUELS

Hydrazones:	Formaldehyde (FH)
	Formaldehyde monomethyl (FMH)
	Formaldehyde dimethyl (FDH)
	Acetaldehyde dimethyl (ADH)
	Polymeric FMH, FDH
Amines:	Dimethyl
	Trimethyl
Others:	Ammonia
	Azomethane
	Formaldazine
	Dimethylforamide
	Detramethyltetrazene
	Acetaldehyde
	1-methyl - 1,2,4-triazole

### 3. CULTURES

a. Stock Culture. A stock culture of heterotrophic bacteria was maintained in a fill-and-draw, Plexiglas® reactor, 660 mm high and 152 mm in diameter, containing a liquid volume of 10ℓ. Mixing and aeration were by diffused air at a rate of 0.0019 m<sup>3</sup>/min (0.067 cfm). Waste sludge was removed daily to maintain a Solids Retention Time (SRT) of nine days. The inorganic nutrients in the feed are shown in Table 3; Carnation® dry milk was provided as the sole carbon source at a COD of 600 mg/ℓ. Phosphorous, potassium, and buffer capacity were provided through the addition of 4 grams (gm) K<sub>2</sub>HPO<sub>4</sub> and 2 gm KH<sub>2</sub>PO<sub>4</sub> per liter of feed.

TABLE 3. INORGANIC SALTS USED FOR THE GROWTH OF STOCK CULTURE

<u>Source</u>	<u>Mineral</u>	<u>Concentration of Mineral in Feed</u>	
		<u>mg/</u>	<u>mg/mg COD</u>
$\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$	Fe*	6	$1 \times 10^{-2}$
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	Mg*	3	$5 \times 10^{-3}$
$\text{NH}_4\text{CP}$	N	36	0.06
$\text{CaC}_1$	Ca	3	$5 \times 10^{-3}$
$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$	Mn	0.06	$1 \times 10^{-4}$
$\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$	Mo	0.006	$1 \times 10^{-5}$
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	Cu	0.06	$1 \times 10^{-4}$
$\text{ZnCl}_2$	Zn	0.09	$1.5 \times 10^{-4}$
$\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$	Co	0.06	$1 \times 10^{-4}$

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\*Iron, magnesium, and nitrogen solutions were made up at concentrations such that daily additions of 10 mls affected the desired concentrations. All other trace nutrients listed were available from one stock solution, 10 mls of which were added daily to the feed.

Feeding was accomplished once every 24 hours according to a procedure by Joel and Grady (Reference 4).

(1) The air to the reactor was stopped for one minute and the reactor volume adjusted to 10 $\ell$  with deionized water to replace evaporation losses.

(2) The air was turned back on, and the reactor was allowed to mix. Samples were removed for mixed liquor volatile suspended solids (MLVSS) and soluble COD analyses.

(3) A volume of mixed liquor appropriate to maintain the SRT at the desired value was removed from each reactor. This volume was adjusted to account for solids lost in the supernatant on the preceding day.

(4) The air was stopped again for 30 minutes, and the solids were allowed to settle.

(5) The supernatant was decanted down to the 5 $\ell$  mark in each reactor and samples removed for Volatile Suspended Solids (VSS) determination.

(6) Five liters of feed solution were added to each reactor, and the air was started again.

In studies using these organisms, cells were withdrawn from the reactor, washed three times in distilled water, and resuspended in a small volume of distilled water. A mixed liquor volatile suspended solids test was performed according to the 14th edition of Standard Methods and the cell suspension adjusted to 2000 mg/ $\ell$  with additional distilled water.

b. Trickling Filter Organisms. For the second group of Warburg studies, trickling filter organisms from the Tyndall Air Force Base trickling filter plant were used. Use of these organisms represented a conservative approach in that the trickling filter slime was used in a dispersed growth environment.

The slime was scraped from the rock media, blended in a Waring blender at the lowest setting for one minute; and aerated for 24 hours without substrate before use. The cells were washed three times in a pH 7.4 phosphate buffer (Table 4) and resuspended in a buffer/inorganic salts medium (Table 5). An MLVSS test was performed, and the suspension was adjusted to 875 mg/l.

TABLE 4. PHOSPHATE BUFFER COMPOSITION

<u>Constituent</u>	<u>Concentration (gm/l)</u>
$\text{KH}_2\text{PO}_4$	8.5
$\text{K}_2\text{HPO}_4$	21.75
$\text{Na}_2\text{HPO}_4 \cdot 7\text{H}_2\text{O}$	33.4
$\text{NH}_4\text{Cl}$	1.7

TABLE 5. BUFFER/INORGANIC SALTS MEDIUM

<u>Constituent</u>	<u>Volume/Liter</u>	<u>Reference</u>
Phosphate Buffer	2.5 ml	Table 4
Stock Fe Solution	0.5 ml	Table 3
Stock Mg Solution	0.5 ml	Table 3
Stock N Solution	0.5 ml	Table 3
Stock Trace Nutrient Solution	0.5 ml	Table 3

#### 4. EXPERIMENTAL WORK

a. General. A waste stream containing 500 ppm HZ, 500 ppm MMH, 500 ppm UDMH, and 100 ppm DMNA could, assuming complete oxidation to methanol, contribute a waste load of 1450 mg/l COD after chlorination. For a flow of 2000 gallons per day, this represents an additional 24 pounds of COD per day to the RMA trickling filter which currently treats from 0.06 to 0.1 million gallons per day (mgd) of domestic wastewater. As the current influent Biochemical Oxygen Demand (BOD<sub>5</sub>) is only 20 mg/l, the blend facility discharge would essentially double the present organic loading. However, because the plant is operating at less than 0.01 percent of its design capacity, the limiting factor will most probably be associated with total dissolved solids and/or the presence of any toxic organics produced during chlorinolysis, not COD loading.

b. Pretreatment. Since the chlorinated wastewater is high in chlorides, i.e., over 5000 mg/l, several aliquots of the original sample were passed through a bench-scale, strong-base ion exchange column packed with Amberlite® IRA-938 resin (hydroxyl cycle). An analysis on these effluents confirmed that all chlorides had been removed. These samples were then used in both the toxicity and biodegradation experiments described below. While analysis of the wastewater indicated that methanol was the only major reaction product, several samples were passed through a bed of Calgon F-300 activated carbon at 0.15 gpm/ft<sup>2</sup> prior to the collection of oxygen uptake data. Because most of the potential reaction products discussed thus far should adsorb to some degree and since not all of the partial oxidation products have been identified to date, carbon pretreatment would serve as a rough, screening technique in evaluating the effects of organics (if any) in the chlorinated wastewater. These treated samples were used in the two standard protocols established.

c. Warburg. Two standard Warburg techniques were used in this study; one was designed to evaluate waste toxicity, and one was designed specifically for biodegradability.

In the first technique, sample flasks were set up containing microorganisms, a known concentration of standard substrate (milk or sodium acetate) and wastewater. By comparing uptake in these flasks with the uptake in substrate only, it was possible to make inferences about the effects of the particular wastewater sample on standard substrate degradation.

In the second protocol, flasks containing only microorganisms and wastewater were used. A standard carbon source was not incorporated into the flasks to insure that all oxygen uptake above endogenous was due to microbial degradation of the wastewater sample. Note, however, that a limited number of compounds have been shown to stimulate oxygen uptake even though they are not utilized for energy or synthesis (Reference 5).

d. Stock Culture Studies. The various components in the Warburg flasks for the stock culture studies were as summarized in Table 6. All runs were made with a thermobarometer flask containing 3.2 mls of distilled water and two endogenous flasks containing 2 mls of distilled water and 1 ml of stock culture cells. Those flasks calling for standard substrate (milk) were made up with an initial food (Milk-COD) to microorganism ratio (F/M) of 0.3 equal to that in the fill and draw reactor. All flasks had an inorganic-salts to microorganism ratio equal to that in the fill and draw reactor.

e. Filter Organism Studies. All runs were made with a thermobarometer flask containing 4.2 mls of phosphate buffer and two endogenous flasks containing 2 mls of distilled water, 1 ml of the buffer/salts medium and 1 ml of cells. Those flasks calling for standard substrate (sodium acetate) were prepared with an initial COD-to-microorganism ratio of 0.3, a high estimate of the organic loading at RMA (0.06) based on a uniform slime thickness of 2 mm. As each flask was made up to 4.0 mls, dilution of the wastewater samples was very conservative (1:4) compared to expected dilutions at RMA (1:30)\*. Table 7 summarizes the matrix established for these experiments.

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\*Based on low domestic flow of 0.06 MGD and high blend facility discharge of 2000 gallons per second (gpd).

TABLE 6. STOCK CULTURE FLASK MATRIX

<u>Flask No.</u>	<u>Date</u>	<u>Components</u>
4:5	8 Dec	1 ml cells 1 ml Carnation® milk feed with inorganic salts 1 ml distilled water
6:7	8 Dec	1 ml cells 1 ml Carnation® milk feed with inorganic salts 1 ml IITRI wastewater
8:9	8 Dec	1 ml cells 1 ml Carnation® milk feed with inorganic salts 1 ml IITRI wastewater with chlorides removed (pH 12)
14:15	8 Dec	1 ml cells 1 ml Carnation® milk feed with inorganic salts 1 ml of IITRI wastewater treated with activated carbon
14:15	19 Jan	1 ml cells 1 ml Carnation® milk feed with inorganic salts 1 ml of IITRI wastewater with chlor- ides removed (pH7)
8:9	19 Jan	1 ml cells 1 ml IITRI wastewater 1 ml inorganic salts
10:11	19 Jan	1 ml cells 1 ml IITRI wastewater with chlorides removed (pH 7) 1 ml inorganic salts
12:13	19 Jan	1 ml cells 1 ml inorganic salts 1 ml IITRI wastewater treated with activated carbon

TABLE 7. FILTER ORGANISM FLASK MATRIX

<u>Flask No.</u>	<u>Date</u>	<u>Components</u>
6:7	2 Jan	1 ml cells in buffer 1 ml inorganic salts 1 ml sodium acetate 1 ml distilled water
10:11	2 Jan	1 ml cells in buffer 1 ml inorganic salts 1 ml sodium acetate 1 ml IITRI wastewater
16	2 Jan	1 ml cells in buffer 1 ml inorganic salts 1 ml sodium acetate 1 ml IITRI wastewater treated with activated carbon
12:13	2 Jan	1 ml cells in buffer 1 ml inorganic salts 1 ml sodium acetate 1 ml IITRI wastewater minus chlorides (pH7.0)
4:5	2 Jan	1 ml cells in buffer 1 ml inorganic salts 1 ml IITRI wastewater 1 ml distilled water
8:9	2 Jan	1 ml cells in buffer 1 ml inorganic salts 1 ml IITRI wastewater minus chlorides (pH 7.0) 1 ml distilled water
14:15	2 Jan	1 ml cells in buffer 1 ml inorganic salts 1 ml IITRI wastewater treated with activated carbon 1 ml distilled water

## SECTION III

### RESULTS AND DISCUSSION

#### 1. TOXICITY

a. Stock Culture Organisms. The effect of chlorinolysis wastewater (referred to as IITRI wastewater) on the respiration of stock culture organisms is shown in Figure 1. Each point has been corrected for endogenous respiration and represents the mean of duplicate flasks. The raw data have been summarized in Appendix A.

The Carnation® milk shows a cumulative oxygen uptake of 235 $\mu$ l expected based on a measured COD of (0.036 mg COD/mg milk solids). All of the milk and approximately 50  $\mu$ l of IITRI wastewater, were recovered as oxygen uptake, for the sample containing both milk and wastewater, indicating that the chlorinolysis effluent did not inhibit these organisms with respect to standard substrate oxidation.

b. Trickling filter Organisms. Figure 2 shows that the IITRI wastewater exhibited no toxic effects on the respiration of trickling filter organisms. However, a lag period of about 24 hours occurred before any significant oxygen utilization was observed.

Many reasons can be postulated for such a response. A lower concentration of trickling filter organisms was used in these experiments, i.e., 875 mg/l versus 2000 mg/l for the stock culture runs. Furthermore, the trickling filter organisms which are normally found in a fixed-film environment were operating in a dispersed growth mode. One important aspect of the oxygen progression shown in Figure 2 is the higher oxygen uptake (105 $\mu$ l ) attributed to the IITRI wastewater in the presence of trickling filter organisms than the stock culture organisms (50 $\mu$ l ).

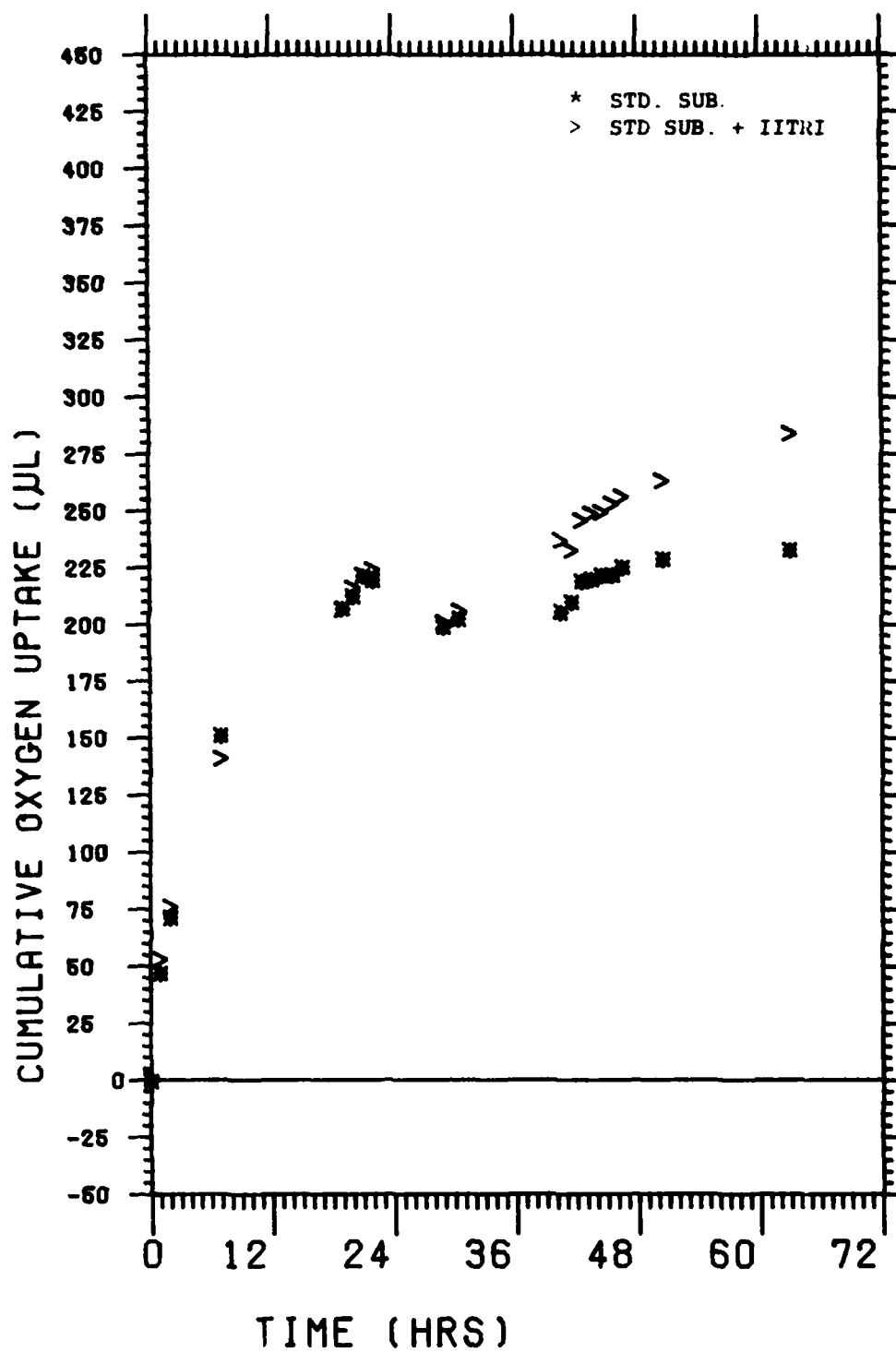


Figure 1. The Effect of IITRI Wastewater on the Respiration of Stock Culture Organisms

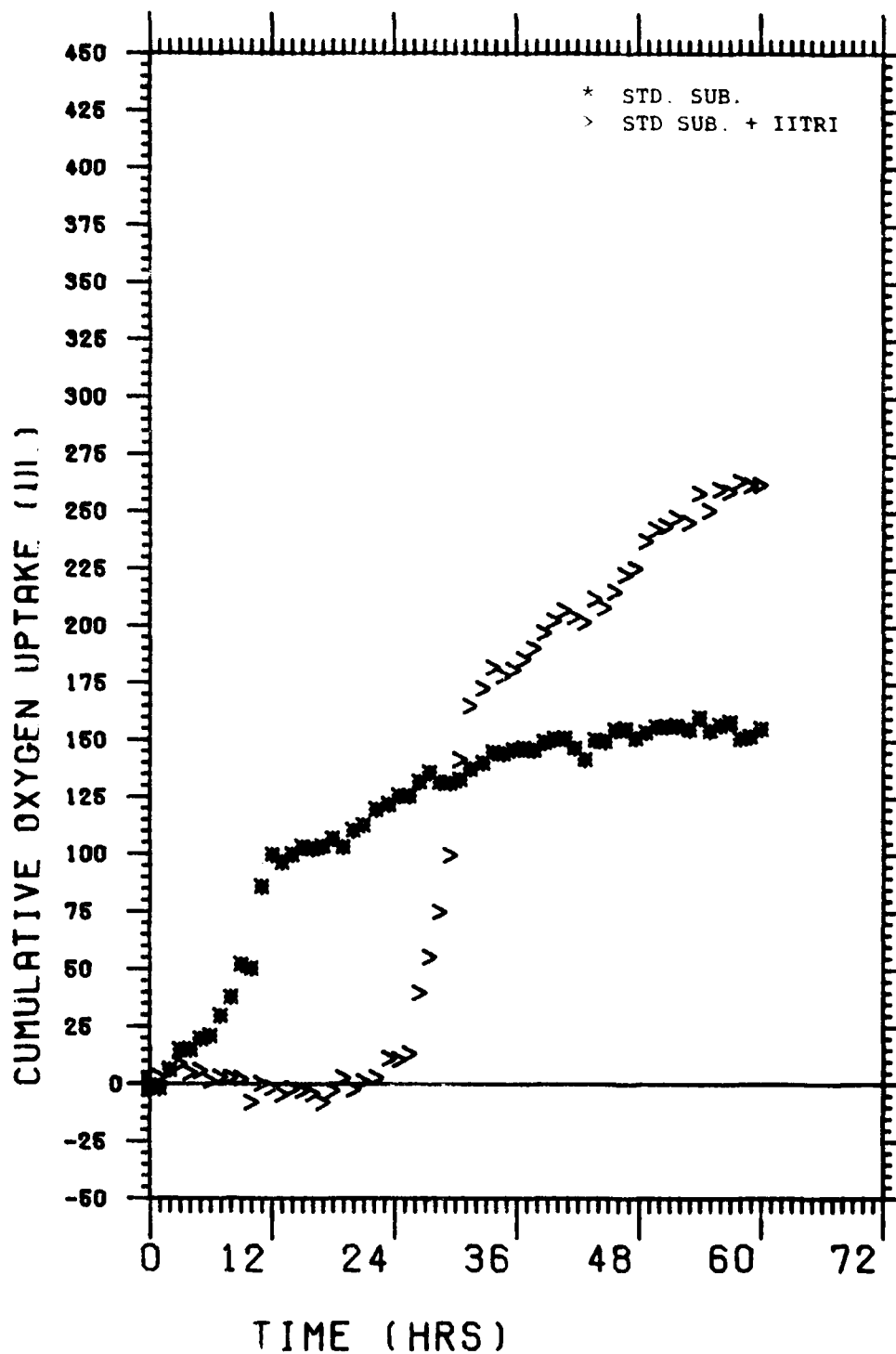


Figure 2. Effects of IITRI Wastewater on the Respiration of Trickling-Filter Organisms

The filter organisms were better able to degrade the wastewater following an initial acclimation period. If total oxygen uptake per milligram of volatile suspended solids (VSS) is computed, this difference is more evident, i.e., 120  $\mu\text{l}$  /mg filter VSS and 25  $\mu\text{l}$  /mg stock VSS. From these studies, it appears that the chlorinolysis effluent is not toxic and appears to be biodegradable by nonacclimated organisms. However, the effluent itself is better degraded by trickling filter slime by a factor of 5 compared to stock culture organisms.

### c. Pretreatment

(1) Carbon. Figure 3 shows little difference (with respect to stock culture oxygen uptake) between raw IITRI samples and those treated with activated carbon.

These data confirm that chlorination of the wastewater was complete and that no partial oxidation or chlorinated end products were present in the samples tested.

As would be expected from the stock culture data, treating the wastewater with carbon had no impact on the uptake curve for filter organisms. The results are summarized in Figure 4.

(2) Ion Exchange. Pretreatment with ion exchange to remove the high concentration of chlorides significantly reduced the toxicity of the chlorinolysis effluent to the stock culture organisms as shown in Figure 5.

The mean total oxygen uptake for the Carnation® with treated IITRI wastewater samples was 400  $\mu\text{l}$  (170  $\mu\text{l}$  of uptake attributed to the IITRI wastewater). This represents a three-fold increase in uptake over the sample containing the high concentration of chlorides. The observed advantages associated with the reduced osmotic pressure may well be realized through dilution of the blend facility effluent at the RMA filter with the domestic flow.

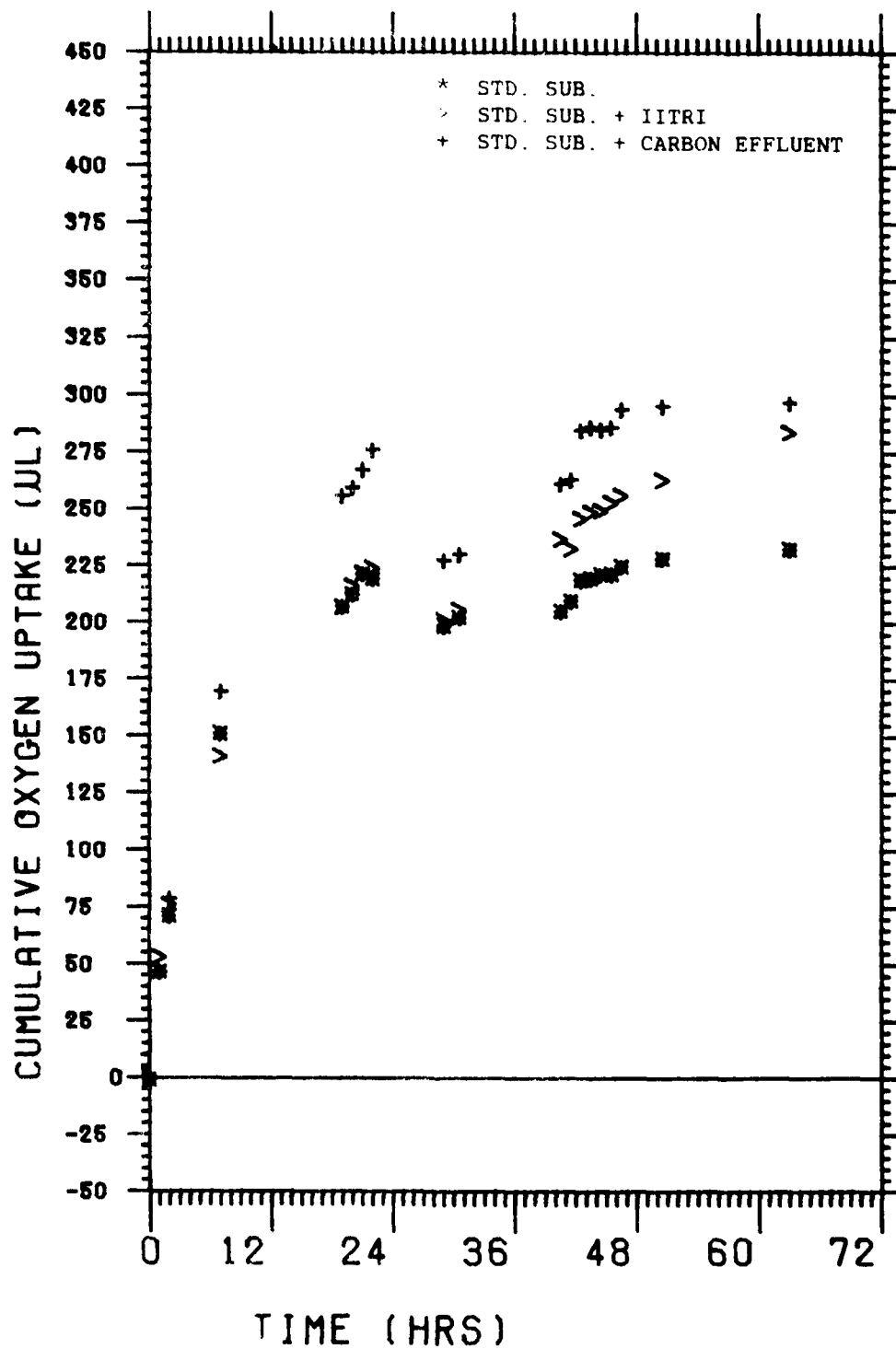


Figure 3. The Effect of Activated Carbon Pretreatment on the Toxicity of IITRI Wastewater to Stock Culture Organisms

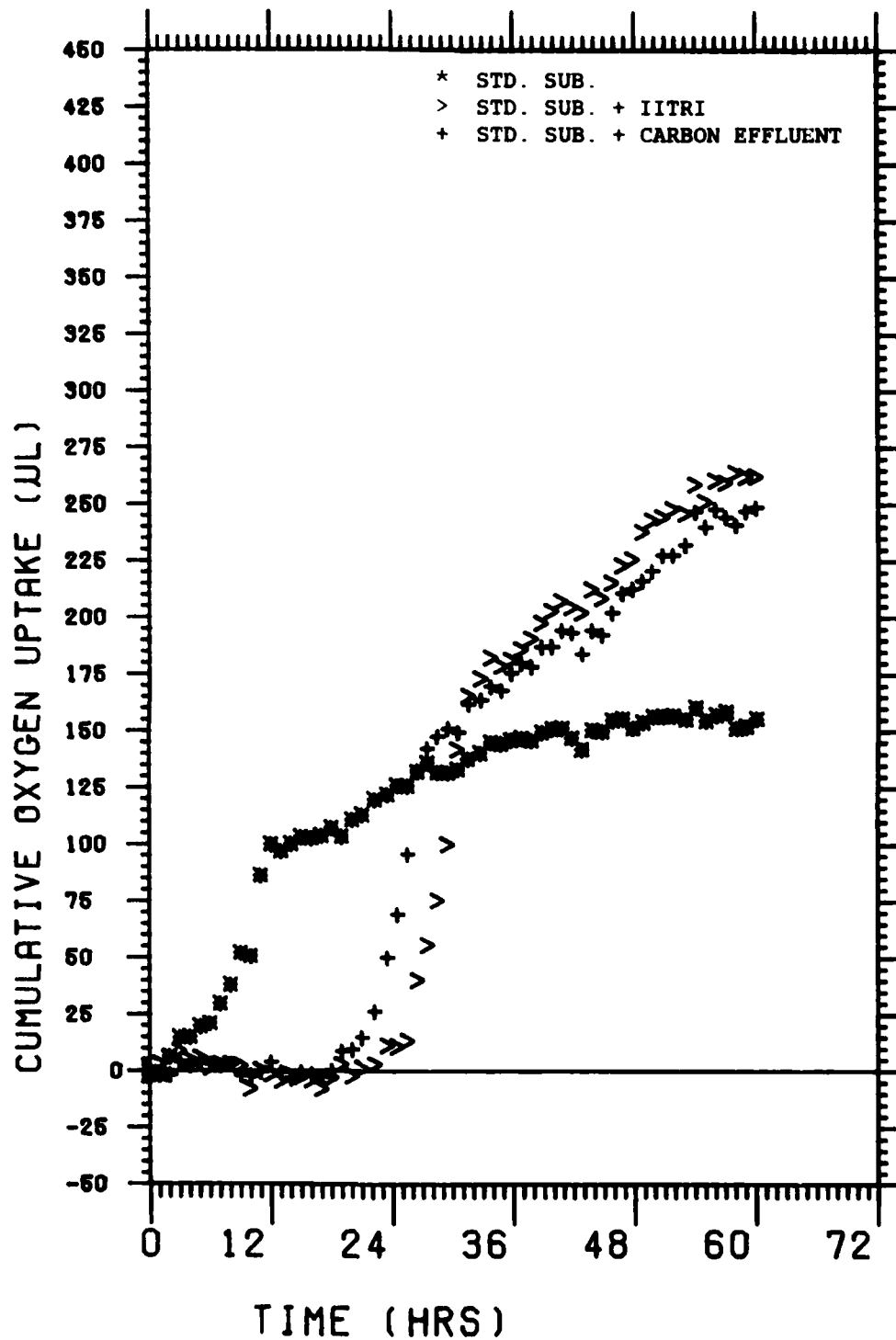


Figure 4. The Effects of Activated Carbon Pretreatment on the Toxicity of IITRI Wastewater to Trickling Filter Organisms

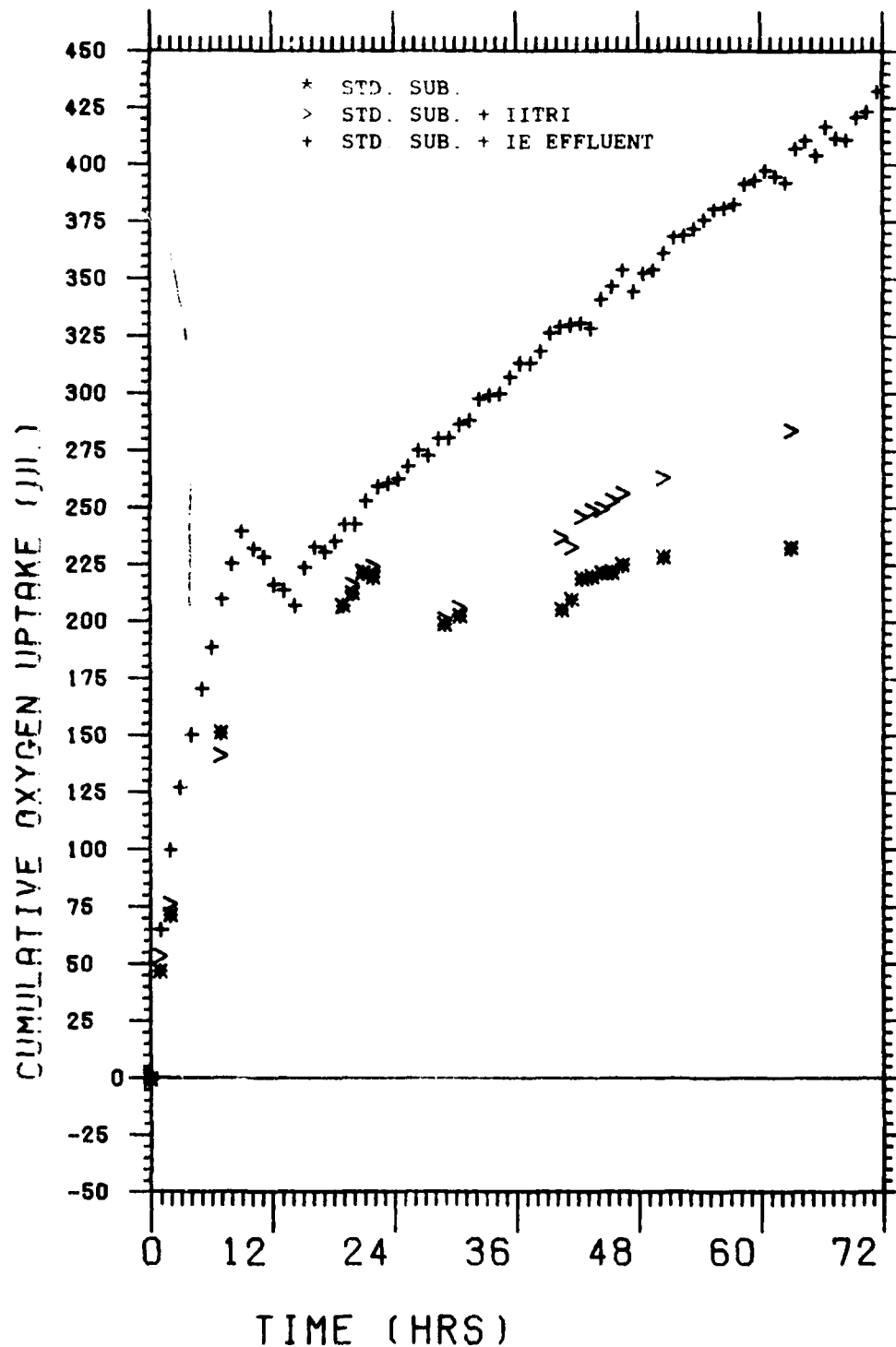


Figure 5. The Effect of Ion Exchange Pretreatment on the Toxicity of IITRI to Stock Culture Organisms

Figure 6 demonstrates the need to adjust the pH from 12 back into the biological range following pretreatment with strong base resin. The negative oxygen uptake indicates no microbial activity.

Ion exchange pretreatment had little effect on the uptake of standard substrate by filter organisms as shown in Figure 7.

The difference between stock and filter organism response to elevated osmotic pressure as demonstrated in these experiments is attributed to population dynamics. As biological principles would predict, the more specialized milk grown population was less tolerant to such an environmental change than the more heterogenous filter population.

## 2. BIODEGRADABILITY

a. Stock Culture Organisms. Figure 8 illustrates the biodegradability of the IITRI wastewaters by stock culture organisms. The cumulative uptake of 75  $\mu\text{l}$  for the chlorinolysis effluent compares well with that value of 50  $\mu\text{l}$  reported in the toxicity section.

Cumulative oxygen uptake values observed for the IITRI carbon column effluent also agree with the values obtained by difference using the Carnation® dry milk. IITRI wastewater treated with carbon gave a cumulative oxygen uptake value of 65  $\mu\text{l}$  with microorganisms only and 70  $\mu\text{l}$  when calculated by difference.

Pretreatment with ion exchange had a pronounced effect on the biodegradability of the wastewater, indicating that degradation can be increased by a factor of nearly 3 in the absence of TDS. Again the cumulative uptake shown in Figure 8 for this sample, 250  $\mu\text{l}$  (357 mg/ BOD), correlates well with the 200  $\mu\text{l}$  observed

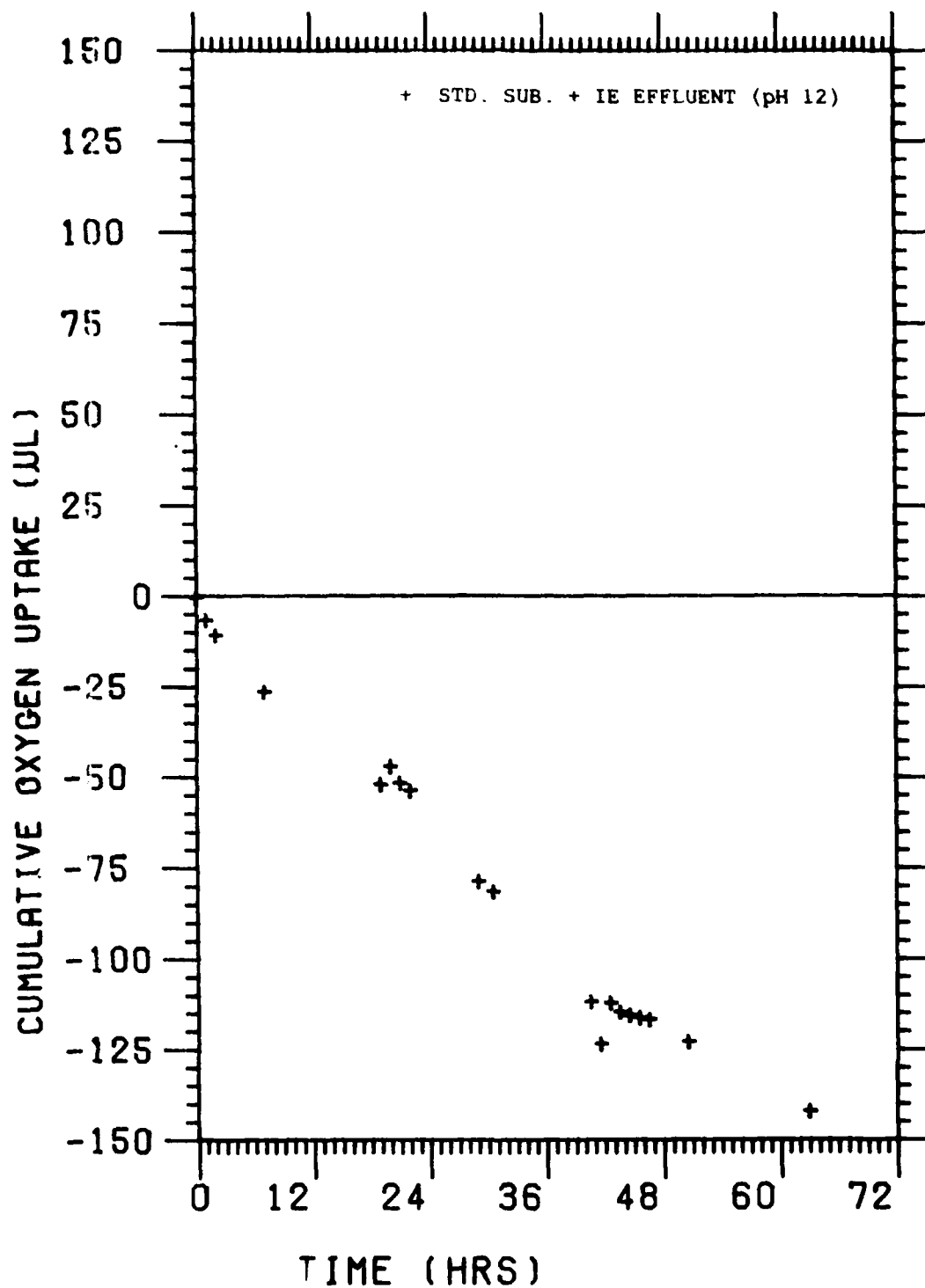


Figure 6. The Effect of Ion Exchange Pretreatment Without pH Adjustment on the Toxicity of IITRI Wastewater to Stock Culture Organisms

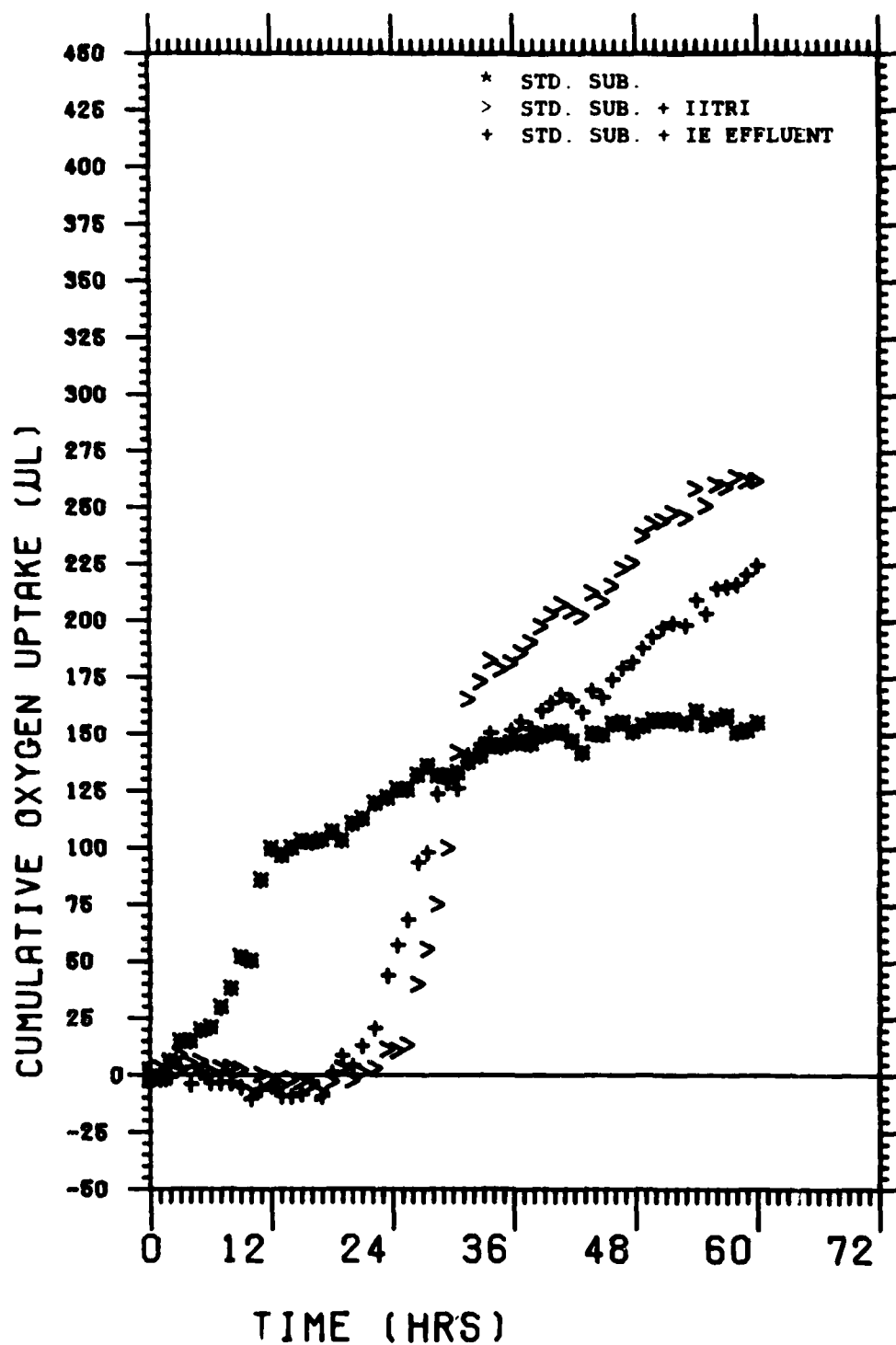


Figure 7. The Effect of Ion Pretreatment on the Toxicity of IITRI Wastewater to Trickling Filter Organisms

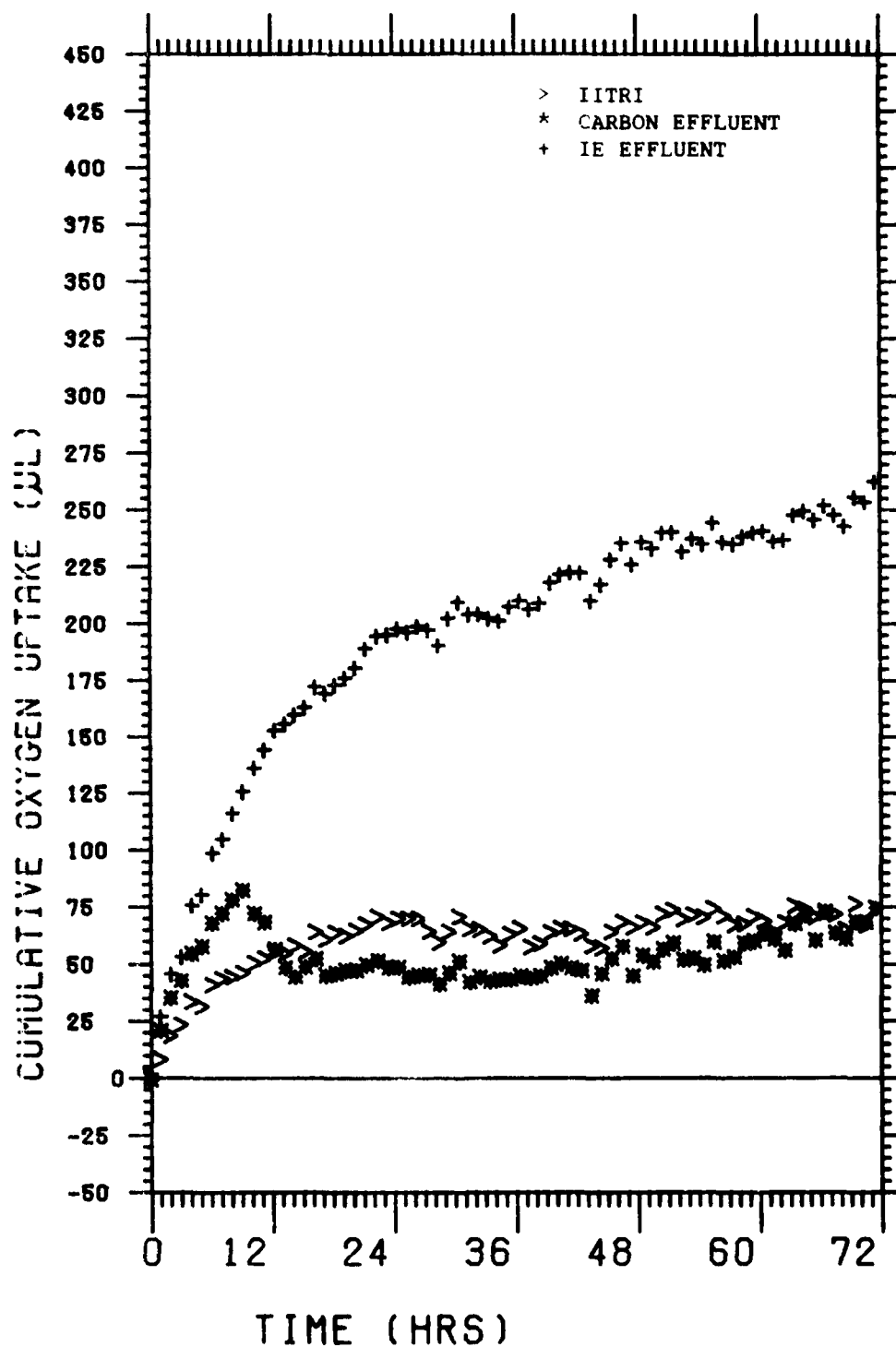


Figure 8. Biodegradability of IITRI Wastewaters by Stock Culture Organisms

during the toxicity experiments. It is obvious from these and previous data that the high concentration of chlorides is inhibitory to the stock culture organisms.

b. Trickling Filter Organisms. The data in Figure 9 confirm that pretreatment with activated carbon and ion exchange have no effect on the biodegradability of the IITRI wastewater by filter organisms. It is degradable but the required acclimation period of some 24 hours is again evident.

This lag time should not present operational problems in a continuous flow trickling filter plant once steady state is achieved. The mean cumulative uptake for all three samples,  $100\mu\text{l}$  correlates very well with values obtained by difference during the toxicity experiments (mean =  $97\mu\text{l}$ ).

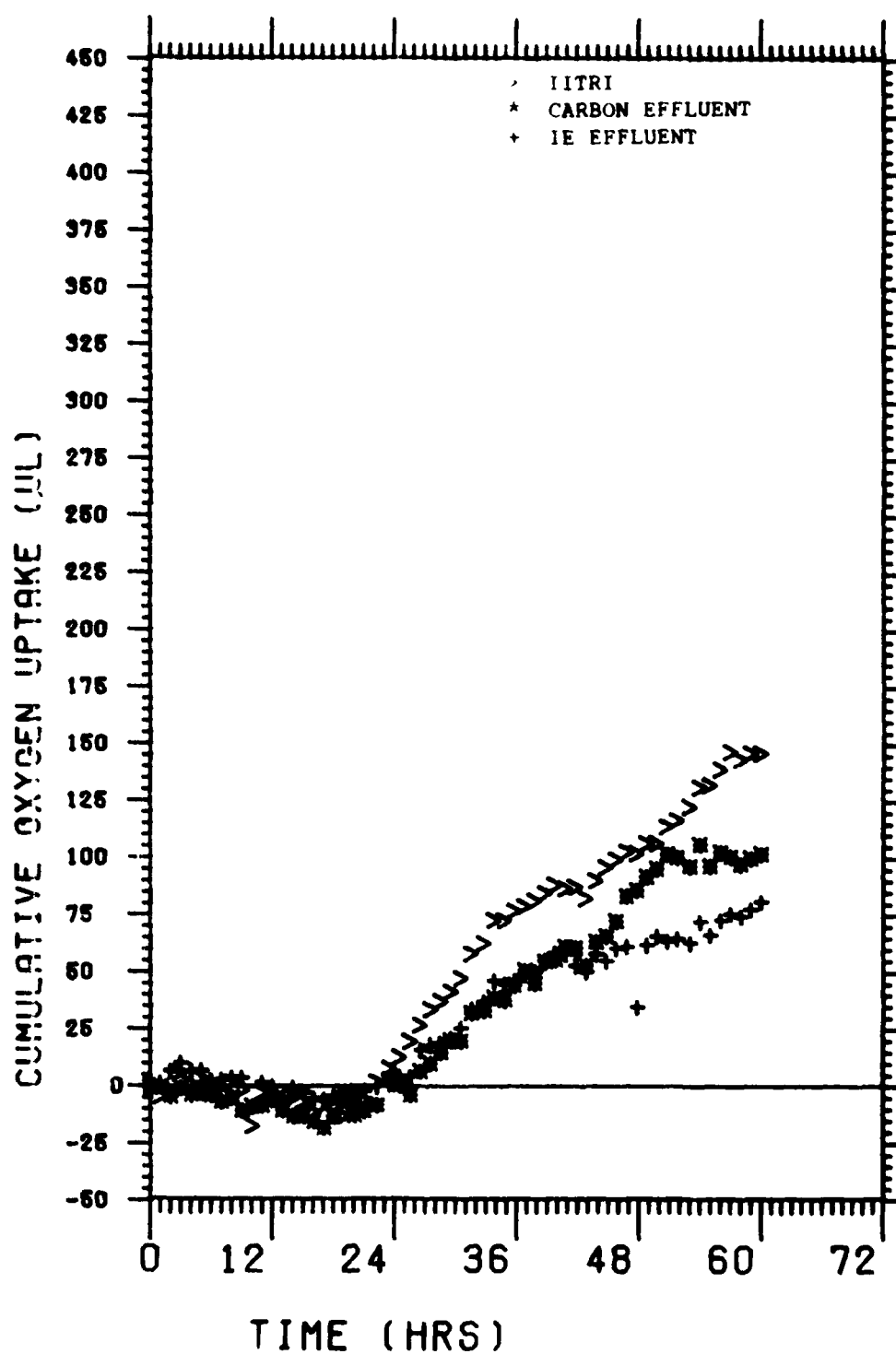


Figure 9. Biodegradability of IITRI Wastewater by Trickling Filter Organisms

## SECTION IV

### SUMMARY

Investigations involving standard substrates and untreated IITRI wastewater indicated that substrate inhibition does not occur in either stock cultures or trickling filter slimes. Unlike the stock culture organisms, trickling filter biomass consistently required some 24 hours to acclimate to all forms of the wastewater. This phenomenon has been attributed to the protocol employed, i.e., these slimes were evaluated in a dispersed growth environment and maintained on unfamiliar (yet very degradable) substrate (NaAc). However, under steady-state conditions (continuous blend facility discharge), this observed lag should pose no operational problems after an initial acclimation period.

Biodegradation data confirmed that IITRI wastewater does not inhibit those organisms tested and showed, in fact, that the waste itself can be recovered, to some extent, as oxygen uptake. On a per mg VSS basis, the trickling filter biomass is better able to degrade the wastewater by a factor of 5.

Activated carbon pretreatment data suggest that no chlorinated hydrocarbons or incomplete oxidation products were formed during the UV-chlorinolysis process. Cumulative oxygen uptakes for these samples were very comparable in both the toxicity and biodegradation protocols. Ion exchange pretreatment significantly reduced dissolved solids. The stock culture organisms responded with a three-fold increase in cumulative oxygen uptake whereas the filter organisms showed no significant change in degradation.

These trends are well illustrated in Table 8 which is a summary of 60-hour, oxygen-uptake values for the experimental matrix. These values, which were easily calculated using the conversion  $1 \mu\text{l}/0.00143 \text{ mg O}_2$  (assuming standard temperature and pressure), were determined both directly (biodegradation protocol) and by difference (toxicity protocol).

TABLE 8. SIXTY-HOUR OXYGEN UPTAKE SUMMARY

STOCK CULTURE			FILTER ORGANISMS			
Toxicity Protocol			Degradation Protocol		Degradation Protocol	
Pretreatment	Substandard Substrate ( $\mu\ell$ )	Std. Sub. plus waste ( $\mu\ell$ )	Waste ( $\text{mgO}_2/\ell/\text{mg vss}$ )	Standard Substrate ( $\mu\ell$ )	Std. Sub. plus waste ( $\mu\ell$ )	Waste ( $\text{mgO}_2/\ell/\text{mg vss}$ )
	230	280	0.036	155	260	0.172
	230	300	0.050	155	250	0.155
	230	400	0.122	155	255	0.114
NONE						0.237
CARBON						0.163
ION EXCHANGE						0.131

## SECTION V

### CONCLUSIONS

1. UV-chlorinolysis of a solution containing 500 ppm each Hz, MMH, UDMH, and DMNA produced an effluent which was not toxic to stock culture or trickling filter heterotrophic organisms.
2. The wastewater itself exerts an oxygen demand of approximately 150 mg/l in the presence of 875 mg/l volatile trickling filter solids. Ion exchange pretreatment did not significantly change this value.
3. In the presence of a milk solids-reared, dispersed growth stock culture (2000 mg/l MLVSS), ion exchange pretreatment reduced TDS such that cumulative oxygen demand values were increased from 90 mg/l to 335 mg/l.
4. Current flows at RMA should insure sufficient dilution such that actual chlorinated effluent/organism ratios will be 7 to 8 times lower than those investigated here.
5. Carbon adsorption pretreatment had little effect on toxicity and degradability of the wastewater, indicating that chlorinated organics, amines, and/or incomplete oxidation products were not formed in the effluent studied.

## SECTION VI

### REFERENCES

1. Koch, Roger, "Wastewater Treatment System for Hydrazine Fuel Mixing Facility at Rocky Mountain Arsenal" IIT/Research Institute, Chicago, IL, November 1978.
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, American Public Health Association, Washington DC 1975.
3. Yamaguchi, M. et al, "Anal. Biochemistry" Vol 16, 1966.
4. Joel, Arnon R., and C. P. L. Grady III, "Inhibition of Nitrification - Effects on Aniline After Biodegradation," Journal Water Pollution Control Federation, May 1977.
5. Umbriet, W. W. and J. F. Stauffer, Manometric Techniques, 5th edition, Burgess Publishing Co., Minneapolis 1972.

APPENDIX A

STOCK CULTURE

DUPLICATE FLASK DATA

# AVERAGE CORRECTED WARBURG DATA

SAMPLES AVERAGED: Carnation®/Carnation®

TEST TIME (HRS)	FLASK NO. 5 UPTAKE SUM (UL)	FLASK NO. 7 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	49.1	52.8	47.4
2.00	59.8	58.0	71.9
3.00	142.1	161.3	151.7
4.00	153.6	222.1	207.5
5.00	164.8	261.3	213.0
6.00	177.4	266.5	222.0
7.00	188.1	271.1	220.1
8.00	184.9	234.1	199.5
9.00	185.8	240.5	203.2
10.00	187.7	254.5	206.1
11.00	183.2	258.2	210.7
12.00	175.2	265.4	219.8
13.00	172.1	269.4	220.5
14.00	174.8	259.9	222.4
15.00	174.0	270.9	222.9
16.00	175.6	276.2	225.9
17.00	176.3	232.4	229.4
18.00	180.3	256.7	233.5

SAMPLES AVERAGED: Carnation® + IITRI/Carnation® + IITRI

TEST TIME (HRS)	FLASK NO. 5 UPTAKE SUM (UL)	FLASK NO. 7 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	51.1	53.8	52.5
2.00	71.5	79.1	75.3
3.00	134.5	146.1	140.3
4.00	196.5	214.9	205.8
5.00	205.2	225.5	215.4
6.00	211.6	230.5	221.1
7.00	213.7	233.0	223.3
8.00	184.5	219.6	200.1
9.00	185.3	214.9	205.1
10.00	224.1	245.5	236.3
11.00	225.9	243.3	232.1
12.00	232.2	255.5	245.3
13.00	235.7	260.3	248.2
14.00	236.3	261.5	248.9
15.00	245.6	254.3	252.5
16.00	263.6	267.6	265.6
17.00	257.1	262.9	262.5
18.00	271.3	275.9	283.3

SAMPLES AVERAGED: Carnation® + IITRI-C1s/  
Carnation® + IITRI-C1s

DATE - DEC 8, 1978

FLASK NOS. 8/9

TEST TIME (HRS)	FLASK 8 UPTAKE SUM (UL)	FLASK 9 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	-1.2	-11.4	-5.3
2.00	-2.8	-18.1	-10.4
3.00	-14.2	-32.8	-26.0
4.00	-46.4	-56.7	-51.0
5.00	-41.3	-51.7	-46.5
6.00	-46.8	-55.5	-51.1
7.00	-49.8	-56.7	-53.2
8.00	-75.5	-80.8	-78.2
9.00	-78.3	-83.5	-80.9
10.00	-95.0	-127.4	-111.2
11.00	-111.7	-134.0	-122.9
12.00	-100.5	-122.7	-111.6
13.00	-102.1	-126.0	-114.0
14.00	-101.4	-128.7	-115.1
15.00	-102.2	-129.5	-115.8
16.00	-104.3	-128.2	-116.2
17.00	-107.9	-136.9	-122.4
18.00	-115.6	-164.8	-141.7

SAMPLES AVERAGED: Carnation® + IITRI CCE  
Carnation® + IITRI CCE

DATE - DEC 8, 1978

FLASK NOS. 14/15

TEST TIME (HRS)	FLASK 14 UPTAKE SUM (UL)	FLASK 15 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	47.9	47.0	47.4
2.00	74.3	74.6	74.5
3.00	170.1	170.2	170.2
4.00	257.6	255.7	256.6
5.00	261.2	259.2	260.2
6.00	258.3	267.9	268.1
7.00	276.3	277.5	276.9
8.00	228.6	228.4	228.5
9.00	231.3	231.0	231.1
10.00	262.5	261.4	262.1
11.00	262.9	265.1	264.0
12.00	283.7	287.4	285.6
13.00	255.2	288.0	287.1
14.00	285.3	287.0	286.1
15.00	285.2	288.0	287.1
16.00	293.3	296.5	294.9
17.00	295.7	297.0	296.3
18.00	294.0	301.8	297.9

SAMPLES AVERAGED: IITRI-C1S/IITRI-C1S

DATE-JAN 19, 1979

FLASK NOS. 10/11

TEST TIME (HRS)	FLASK 10 UPTAKE SUM (UL)	FLASK 11 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	29.0	26.9	27.9
2.00	44.2	49.0	46.5
3.00	51.0	57.4	54.2
4.08	74.4	78.8	76.5
5.08	79.5	83.6	81.5
6.08	97.7	101.7	99.7
7.08	103.8	107.5	105.7
8.08	115.2	118.7	117.0
9.08	125.8	127.4	126.5
10.25	136.4	137.7	137.1
11.25	147.1	142.9	145.1
12.25	155.0	151.6	153.3
13.25	158.8	154.4	156.5
14.25	163.9	157.6	160.7
15.25	164.5	163.5	164.0
16.25	174.6	171.5	173.1
17.25	172.5	167.6	170.0
18.25	176.2	171.4	173.8
19.25	178.4	175.2	176.8
20.25	182.9	179.6	181.3
21.25	188.1	191.8	189.9
22.42	192.6	198.1	195.3
23.42	193.2	198.6	195.9
24.42	196.0	201.3	198.7
25.42	195.4	198.7	197.0
26.42	197.0	202.2	199.6
27.42	194.6	201.6	198.1
28.42	187.7	194.6	191.2
29.42	198.8	207.5	203.1
30.42	206.8	213.5	210.1
31.42	202.2	207.2	204.7
32.42	203.6	206.6	205.1
33.42	201.7	204.7	203.2
34.42	199.7	204.5	202.1
35.42	206.0	210.6	208.3
36.42	209.5	212.3	210.9

SAMPLES AVERAGED: IITRI-CLS/IITRI-CLS (Continued)

37.42	203.2	211.3	207.2
38.42	205.7	213.4	209.5
39.42	214.7	222.7	215.7
40.42	218.4	226.3	222.3
41.42	219.2	227.1	223.2
42.42	218.2	227.4	223.0
43.42	208.8	213.0	219.9
44.42	213.3	222.9	218.1
45.42	224.3	233.8	229.1
46.50	232.5	240.1	235.3
47.50	223.1	230.8	227.0
48.50	231.2	242.3	236.7
49.50	229.2	238.5	233.8
50.50	236.4	245.6	241.0
51.50	236.4	245.6	241.0
52.50	228.1	237.3	232.7
53.50	232.7	243.7	236.2
54.50	231.4	240.5	235.4
55.50	234.8	250.5	245.1
56.50	233.1	240.3	236.7
57.50	230.3	241.1	235.7
58.50	233.8	244.5	236.2
59.50	236.4	245.2	240.3
60.50	236.3	246.9	241.5
61.50	231.8	242.4	237.1
62.50	232.5	243.1	237.3
63.50	242.3	254.6	247.5
64.50	243.3	257.3	250.3
65.50	241.2	251.6	246.4
66.50	244.9	260.6	252.3
67.50	242.6	254.6	246.6
68.50	236.6	250.5	243.5
69.50	249.4	263.2	257.3
70.50	246.3	261.9	254.1
71.50	255.5	270.9	263.2

SAMPLES AVERAGED: IITRI/IITRI

DATE-JAN 19, 1979

FLASK NOS. 8/ 9

TEST TIME (HRS)	FLASK 8 UPTAKE SUM (UL)	FLASK 9 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	5.1	10.1	7.5
2.00	15.5	20.6	18.1
3.00	21.2	24.3	22.8
4.00	31.2	34.3	32.8
5.00	28.5	33.2	30.8
6.00	38.9	41.9	40.4
7.00	42.3	43.5	42.9
8.00	42.3	45.1	43.7
9.00	45.0	46.1	45.5
10.00	44.4	50.4	47.4
11.00	50.6	53.2	51.9
12.00	53.5	56.1	54.8
13.00	52.8	55.5	54.1
14.00	55.3	54.6	57.5
15.00	52.0	57.9	54.4
16.00	61.4	65.5	63.5
17.00	58.9	61.4	60.2
18.00	61.1	65.3	63.2
19.00	60.5	62.9	61.7
20.00	62.9	65.2	64.1
21.00	65.5	67.8	66.7
22.00	64.8	70.3	67.0
23.00	66.4	68.6	67.5
24.00	64.1	64.6	64.4
25.00	64.2	64.6	64.4
26.00	68.9	64.3	64.1
27.00	63.3	63.8	63.5
28.00	59.5	58.2	58.9
29.00	63.4	63.8	63.6
30.00	70.7	64.3	70.0
31.00	64.5	64.4	64.7
32.00	65.1	63.7	64.4
33.00	63.1	60.0	61.5
34.00	54.2	56.1	57.7
35.00	63.2	61.7	62.5
36.00	66.4	63.2	64.8
37.00	58.5	55.3	56.9

SAMPLES AVERAGED: IITRI/IITRI (Continued)

34.42	59.0	57.5	58.3
39.42	64.0	62.4	63.2
40.42	65.7	64.1	64.3
41.42	66.3	63.1	64.7
42.42	63.5	61.9	62.7
43.42	58.9	55.6	57.3
44.42	58.1	54.8	56.5
45.42	65.3	62.0	63.7
46.50	69.5	66.2	67.5
47.50	68.8	62.0	65.4
48.50	71.1	64.3	67.7
49.50	70.6	60.4	65.5
50.50	77.3	65.3	71.3
51.50	80.7	65.3	73.0
52.50	79.2	58.8	69.0
53.50	82.0	59.8	70.9
54.50	80.1	54.6	64.3
55.50	83.0	64.2	73.5
56.50	79.8	60.9	70.5
57.50	75.1	58.0	66.6
58.50	74.8	54.3	67.1
59.50	77.1	63.3	70.2
60.50	75.0	61.2	68.1
61.50	69.0	56.9	63.0
62.50	72.8	62.4	67.5
63.50	78.5	71.4	74.4
64.50	76.0	70.5	73.3
65.50	71.8	68.1	70.0
66.50	73.6	69.9	71.7
67.50	73.9	68.4	71.2
68.50	67.2	61.8	64.5
69.50	72.6	78.9	75.7
70.50	67.4	65.2	66.3
71.50	74.3	73.9	74.1

SAMPLES AVERAGED: IITRI-Cls (pH7)/IITRI-Cls (pH7)

DATE - JAN 19, 1979 FLASK NOS. 14/15

TEST TIME (HRS)	FLASK 14 UPTAKE SUM (UL)	FLASK 15 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	72.4	54.7	65.6
2.00	107.5	93.2	100.4
3.00	137.9	117.4	127.6
4.00	161.3	140.5	150.9
5.00	182.6	159.5	171.1
6.00	200.9	177.5	189.2
7.00	221.4	194.3	210.3
8.00	238.3	213.9	226.1
9.00	252.5	227.8	240.2
10.00	245.0	220.3	232.5
11.00	241.2	216.5	228.8
12.00	228.4	205.5	216.9
13.00	227.6	201.2	214.4
14.00	212.8	202.5	207.6
15.00	236.4	211.9	224.4
16.00	245.1	221.7	233.4
17.00	244.4	217.8	231.3
18.00	250.4	221.6	236.0
19.00	258.1	228.8	243.5
20.00	258.9	227.8	243.4
21.00	269.5	238.1	253.8
22.00	274.0	246.1	260.1
23.00	276.5	246.6	261.5
24.00	279.3	247.6	263.4
25.00	285.3	252.0	268.9
26.00	291.1	260.7	275.9
27.00	290.5	256.6	273.5
28.00	298.1	263.8	281.0
29.00	298.4	264.2	281.3
30.00	304.5	270.2	287.3
31.00	305.4	272.7	289.1
32.00	315.8	281.0	298.4
33.00	317.5	282.7	300.1
34.00	319.2	282.4	300.8

SAMPLES AVERAGED: IITRI-Cls (pH7)/IITRI-Cls (pH7) (Continued)

35.42	325.4	290.2	307.4
36.42	332.6	295.5	314.1
37.42	333.5	294.5	314.3
38.42	337.9	300.6	314.2
39.42	345.1	304.4	327.2
40.42	348.7	311.2	329.4
41.42	344.5	312.0	330.0
42.42	350.3	312.7	331.5
43.42	349.9	308.5	329.2
44.42	361.7	321.9	341.8
45.42	367.3	327.5	347.4
46.50	373.7	335.5	354.5
47.50	364.3	326.2	345.2
48.50	372.3	334.0	353.2
49.50	375.8	333.8	354.8
50.50	384.9	339.1	362.0
51.50	392.1	346.2	369.2
52.50	391.0	348.5	369.0
53.50	393.8	351.4	372.5
54.50	397.9	355.2	376.3
55.50	404.5	358.2	381.3
56.50	403.3	360.4	381.5
57.50	405.9	361.1	383.3
58.50	414.8	369.4	392.3
59.50	415.6	372.4	394.5
60.50	420.9	375.8	398.3
61.50	418.2	373.1	395.5
62.50	415.3	370.2	392.7
63.50	430.6	385.1	407.4
64.50	435.2	387.9	411.5
65.50	427.7	382.1	404.4
66.50	442.2	392.4	417.3
67.50	436.3	388.5	412.4
68.50	435.7	388.2	411.4
69.50	444.4	399.0	421.4
70.50	444.1	399.4	424.2
71.50	458.2	408.4	433.3

SAMPLES AVERAGED: IITRI CCE/IITRI CCE

DATE - JAN 19, 1979

FLASK NOS. 12/13

TEST TIME (HRS)	FLASK 12 UPTAKE SUM (UL)	FLASK 13 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
1.00	0.0	0.0	0.0
1.00	23.8	19.7	21.7
2.00	37.4	34.7	36.1
3.00	44.4	43.0	43.7
4.00	57.2	53.7	55.5
5.00	60.6	55.8	58.2
6.00	71.7	65.9	68.8
7.00	74.3	71.7	73.0
8.00	80.4	77.6	79.0
9.00	85.7	80.8	83.3
10.00	74.5	71.5	73.0
11.00	70.8	67.7	69.2
12.00	59.7	54.9	57.3
13.00	49.5	48.5	49.0
14.00	45.9	44.8	45.3
15.00	52.1	47.1	49.5
16.00	54.9	51.7	53.3
17.00	47.4	44.1	45.7
18.00	47.5	46.1	46.8
19.00	43.9	46.4	45.1
20.00	52.6	43.6	48.1
21.00	54.2	46.4	50.5
22.00	57.0	47.7	52.3
23.00	55.9	42.4	49.2
24.00	55.0	43.3	49.2
25.00	49.1	41.2	45.1
26.00	50.3	41.1	45.7
27.00	50.2	42.3	45.2
28.00	45.2	38.9	42.0
29.00	52.7	41.0	46.8
30.00	53.9	45.2	49.5
31.00	48.9	37.1	43.0
32.00	48.6	41.9	45.3
33.00	46.7	40.0	43.4
34.00	48.4	39.8	44.1
35.00	49.2	38.7	44.0
36.00	51.0	40.5	45.7
37.00	50.1	39.5	44.8
38.00	51.0	40.2	45.5
39.00	56.4	41.9	49.2

SAMPLES AVERAGED: LITRE CONCENTR CCE (Continued)

40.42	54.2	43.7	51.1
41.42	57.3	41.0	45.1
42.42	56.3	39.9	47.1
43.42	43.3	30.5	37.4
44.42	53.3	40.3	45.3
45.42	60.8	45.4	53.3
46.50	67.2	50.4	52.1
47.50	54.2	37.5	47.3
48.50	62.3	47.2	56.7
49.50	60.4	43.4	51.4
50.50	65.4	48.7	57.3
51.50	67.7	52.3	58.8
52.50	54.3	45.7	52.5
53.50	62.2	45.0	53.7
54.50	57.3	43.5	52.5
55.50	64.4	51.4	57.7
56.50	54.1	45.2	52.2
57.50	61.8	46.0	53.4
58.50	67.2	53.0	50.1
59.50	68.0	53.7	60.4
60.50	71.6	57.1	64.4
61.50	68.4	54.5	51.7
62.50	62.4	51.5	57.5
63.50	74.2	63.0	64.5
64.50	78.8	65.8	72.3
65.50	67.6	54.7	61.2
66.50	80.5	67.3	74.4
67.50	71.0	57.7	64.5
68.50	66.7	57.2	51.4
69.50	75.4	62.7	59.3
70.50	74.8	63.2	64.5
71.50	82.2	68.6	75.4

APPENDIX B  
TRICKLING FILTER ORGANISM  
DUPLICATE FLASK DATA

# AVERAGE CORRECTED WARBURG DATA

SAMPLES AVERAGED- NA AC  
NA AC

DATE-JAN 2, 1979

FLASK NOS. 6/ 7

TEST TIME (HRS)	FLASK 6 UPTAKE SUM (UL)	FLASK 7 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	-3.6	1.5	-1.1
2.00	3.6	10.7	7.1
3.00	13.6	17.9	15.8
4.00	12.6	19.1	15.8
5.00	18.9	22.4	20.6
6.00	19.2	24.6	21.9
7.00	27.7	33.7	30.7
8.00	36.5	41.2	38.9
9.00	49.3	56.4	52.8
10.00	47.9	54.9	51.4
11.00	82.4	91.4	86.9
12.00	91.0	110.6	100.8
13.00	92.6	102.6	97.6
14.00	96.7	105.1	100.9
15.00	98.8	109.2	104.0
16.00	98.4	108.6	103.5
17.00	100.1	109.0	104.5
18.00	102.5	113.2	107.9
19.00	98.8	109.5	104.1
20.00	105.9	117.0	111.4
21.00	108.9	118.6	113.8
22.25	119.8	121.4	120.6
23.50	123.7	122.1	122.9
24.50	127.2	126.4	126.8
25.50	127.0	126.3	126.6
26.50	132.3	133.3	132.8
27.50	131.3	142.4	136.9
28.50	131.3	134.0	132.7
29.50	131.1	133.9	132.5
30.50	132.4	135.4	133.9
31.50	138.0	139.2	138.6
32.75	139.6	142.7	141.2
33.75	145.0	146.7	145.9
34.75	144.4	146.3	145.4
35.75	145.1	148.8	146.9
36.75	147.0	148.6	147.8
37.75	145.7	147.9	146.8
38.75	149.2	151.4	150.3
39.75	150.6	153.0	151.8
40.75	151.1	153.3	152.2
41.75	148.4	147.2	147.8
42.75	142.4	143.0	142.7
43.75	151.0	151.6	151.3
44.75	150.4	151.2	150.8
45.75	154.2	156.9	155.6
46.75	155.7	156.8	156.3
47.75	152.5	151.8	152.2
48.75	154.3	155.3	154.8
49.75	156.5	157.8	157.1
50.75	157.4	157.3	157.4
51.75	157.7	157.5	157.6
53.00	156.0	156.2	156.1
54.00	160.4	162.3	161.3
55.00	155.4	155.5	155.4
56.00	157.7	158.0	157.9
57.00	159.1	159.5	159.3
58.00	152.9	151.3	152.1
59.00	155.4	150.4	152.9
60.00	158.8	153.9	156.3

# AVERAGE CORRECTED WARRBURG DATA

SAMPLES AVERAGED- IITRI-CLS  
IITRI-CLS

DATE-JAN 2, 1979

FLASK NOS. 8/ 9

TEST TIME (HRS)	FLASK 8 UPTAKE SUM (UL)	FLASK 9 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	1.3	2.8	2.1
2.00	0.4	8.4	7.6
3.00	10.6	12.0	11.3
4.00	8.1	7.8	7.9
5.00	8.0	7.7	7.9
6.00	3.5	3.2	3.4
7.00	4.0	3.7	3.8
8.00	4.9	4.5	4.7
9.00	4.9	4.5	4.7
10.00	-7.9	-8.1	-8.0
11.00	-2.8	-2.4	-2.6
12.00	1.8	-1.2	.8
13.00	-2.9	-5.0	-3.9
14.00	-1.2	-1.9	.1
15.00	-1.5	-1.9	-1.7
16.00	-5.2	-4.0	-4.6
17.00	-5.0	-5.5	-5.3
18.00	-2.6	-4.7	-3.6
19.00	-3.1	-1.4	-1.7
20.00	-2.4	-2.9	-2.7
21.00	-1.8	-1.5	-1.2
22.25	.3	1.4	.9
23.50	-1.5	3.7	1.6
24.50	4.8	5.6	5.2
25.50	4.6	5.4	5.0
26.50	14.8	18.7	16.8
27.50	17.0	20.9	19.0
28.50	17.0	22.5	19.8
29.50	20.1	23.9	22.0
30.50	24.6	28.4	26.5
31.50	33.5	35.6	34.5
32.75	36.8	38.8	37.8
33.75	47.1	47.4	47.3
34.75	46.5	45.2	45.9
35.75	50.5	44.3	47.4
36.75	52.3	47.8	50.1
37.75	52.8	49.7	51.2
38.75	57.9	54.8	56.3
39.75	60.9	57.8	59.4
40.75	61.4	56.7	59.1
41.75	55.5	52.4	54.0
42.75	52.7	49.6	51.2
43.75	59.7	58.2	59.0
44.75	57.6	54.4	56.0
45.75	63.0	59.8	61.4
46.75	64.6	59.7	62.1
47.75	59.7	11.7	35.7
48.75	63.1	63.1	63.1
49.75	67.0	66.9	67.0
50.75	64.7	64.6	64.7
51.75	65.0	66.5	65.7
53.00	63.4	64.8	64.1
54.00	69.4	77.2	73.3
55.00	62.8	72.2	67.5
56.00	66.8	80.9	73.9
57.00	68.2	85.5	76.8
58.00	61.9	88.9	75.4
59.00	67.6	89.8	78.7
60.00	71.0	93.2	82.1

# AVERAGE CORRECTED WARBURG DATA

SAMPLES AVERAGED- NA AC+IITRI  
NA AC+IITRI

DATE-JAN 2, 1979

FLASK NOS.10/11

TEST TIME (HRS)	FLASK 10 UPTAKE SUM (UL)	FLASK 11 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	5.0	-0.2	2.4
2.00	4.3	-0.7	5.0
3.00	13.3	3.0	8.2
4.00	9.6	-0.8	4.4
5.00	11.2	-0.9	5.2
6.00	8.5	-7.1	2.7
7.00	7.5	-2.9	2.3
8.00	8.4	-3.8	2.3
9.00	8.5	-5.4	1.5
10.00	-1.7	-15.5	-8.6
11.00	6.6	-7.3	-1.4
12.00	5.6	-10.1	-2.3
13.00	2.7	-12.9	-5.1
14.00	5.3	-10.4	-2.5
15.00	4.4	-11.3	-3.5
16.00	2.1	-11.8	-4.6
17.00	-0.9	-16.6	-8.7
18.00	3.5	-10.5	-3.5
19.00	8.3	-4.0	2.2
20.00	4.0	-10.0	-3.0
21.00	7.4	-6.6	0.4
22.25	8.4	-3.9	2.3
23.50	16.1	5.4	10.8
24.50	17.3	3.1	10.2
25.50	18.9	6.5	12.7
26.50	43.2	35.8	39.5
27.50	57.7	51.9	54.8
28.50	76.7	72.5	74.6
29.50	102.4	96.3	99.4
30.50	145.3	137.2	141.2
31.50	162.8	166.7	164.7
32.75	169.8	175.3	172.5
33.75	179.1	184.5	181.8
34.75	177.1	179.1	178.1
35.75	177.9	183.3	180.6
36.75	182.6	188.0	185.3
37.75	187.4	192.7	190.0
38.75	192.6	201.3	197.0
39.75	197.7	206.5	202.1
40.75	201.4	211.8	206.6
41.75	198.7	209.1	203.9
42.75	196.2	206.6	201.4
43.75	204.8	218.7	211.8
44.75	201.0	214.9	208.0
45.75	207.0	222.5	214.7
46.75	212.1	232.7	222.4
47.75	212.2	237.9	225.0
48.75	217.4	256.8	237.1
49.75	223.4	261.0	242.2
50.75	219.6	267.5	243.6
51.75	223.2	271.1	247.1
53.00	220.4	269.9	245.2
54.00	233.3	282.8	258.1
55.00	226.5	274.3	250.4
56.00	235.9	283.7	259.8
57.00	235.8	281.8	258.8
58.00	237.7	288.8	263.2
59.00	236.8	286.2	261.5
60.00	235.1	288.0	261.6

# AVERAGE CORRECTED WARBURG DATA

SAMPLES AVERAGED- NA AC+IITRI-CLS  
NA AC+IITRI-CLS

DATE-JAN 2, 1979

FLASK NOS.12/13

TEST TIME (HRS)	FLASK 12 UPTAKE SUM (UL)	FLASK 13 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	1.7	-2.2	.8
2.00	2.5	-2.7	-1.1
3.00	6.6	1.3	3.9
4.00	2.9	-9.4	-3.2
5.00	4.6	-9.9	1.8
6.00	-1.6	-3.7	-2.7
7.00	-8.8	-4.6	-2.7
8.00	.1	-5.5	-2.7
9.00	-1.6	-7.1	-4.3
10.00	-10.1	-8.7	-9.4
11.00	-3.5	-7.3	-5.4
12.00	-2.7	-4.9	-3.8
13.00	-7.2	-9.5	-8.4
14.00	-4.6	-12.1	-8.4
15.00	-3.8	-11.3	-7.5
16.00	.8	-5.0	-2.1
17.00	-5.6	-11.4	-8.5
18.00	7.5	-3.7	1.9
19.00	16.0	2.9	9.4
20.00	13.3	-3.2	5.1
21.00	25.5	2.0	13.7
22.25	36.9	6.4	21.6
23.50	69.0	20.8	44.9
24.50	93.0	23.7	58.3
25.50	108.6	30.4	69.5
26.50	129.6	59.7	94.6
27.50	130.4	67.3	98.9
28.50	133.9	115.2	124.6
29.50	139.1	120.3	129.7
30.50	140.7	113.3	127.0
31.50	149.7	134.2	141.9
32.75	153.2	139.4	146.3
33.75	160.9	141.8	151.4
34.75	152.0	139.8	145.9
35.75	159.8	145.7	152.7
36.75	162.7	150.4	156.5
37.75	160.7	146.6	153.6
38.75	167.7	155.2	161.4
39.75	173.0	156.9	164.9
40.75	178.3	158.8	168.6
41.75	173.9	157.8	165.8
42.75	169.7	151.9	160.8
43.75	180.1	160.5	170.3
44.75	176.3	158.4	167.4
45.75	185.8	164.4	175.1
46.75	192.7	167.7	180.2
47.75	196.3	169.5	182.9
48.75	205.1	173.0	189.0
49.75	214.7	173.8	194.3
50.75	219.6	176.9	198.2
51.75	226.7	173.6	200.1
53.00	225.7	172.5	199.1
54.00	235.2	185.4	210.3
55.00	226.6	181.9	204.3
56.00	236.2	194.8	215.5
57.00	234.3	198.0	216.2
58.00	229.2	205.0	217.1
59.00	235.3	207.6	221.4
60.00	238.8	212.4	225.8

AVERAGE CORRECTED WARBURG DATA  
 SAMPLES AVERAGED- IITRICCE  
 IITRICCE

DATE-JAN 2, 1979      FLASK NOS.14/15

TEST TIME (HRS)	FLASK 14 UPTAKE SUM (UL)	FLASK 15 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	1.6	-1.2	0.7
2.00	-2.7	-4.4	-3.6
3.00	1.3	-1.5	0.4
4.00	-1.7	-4.4	-2.6
5.00	-1.8	-2.8	-1.8
6.00	-1.9	-3.9	-2.9
7.00	-2.8	-8.2	-5.5
8.00	-1.2	-7.4	-3.8
9.00	-5.3	-14.1	-9.7
10.00	-3.4	-12.2	-7.8
11.00	-1.3	-14.4	-7.3
12.00	2.1	-12.0	-4.9
13.00	-2.4	-16.6	-9.5
14.00	-5.0	-19.1	-12.1
15.00	-4.2	-20.1	-12.2
16.00	-4.8	-24.0	-14.4
17.00	-7.8	-27.0	-17.4
18.00	-1.7	-22.7	-12.2
19.00	6.6	-16.3	-4.8
20.00	-1.2	-22.3	-11.8
21.00	2.3	-22.3	-10.0
22.25	5.0	-19.6	-7.3
23.50	17.8	-10.4	3.7
24.50	15.5	-12.8	1.4
25.50	12.0	-18.0	-3.0
26.50	22.5	-7.5	7.5
27.50	26.8	-5.1	10.8
28.50	31.9	-1.0	16.0
29.50	37.0	4.9	21.0
30.50	36.9	4.8	20.8
31.50	51.0	15.3	33.2
32.75	52.8	15.4	34.1
33.75	58.7	21.2	39.9
34.75	56.7	20.8	38.8
35.75	62.6	28.3	45.5
36.75	69.0	34.8	51.9
37.75	63.5	29.2	46.3
38.75	72.2	39.4	55.8
39.75	72.2	41.1	56.6
40.75	77.5	46.4	62.0
41.75	76.5	47.1	61.8
42.75	68.9	39.5	54.2
43.75	77.5	51.5	64.5
44.75	80.6	52.7	66.7
45.75	86.6	60.2	73.4
46.75	96.8	72.0	84.4
47.75	98.6	75.4	87.0
48.75	105.6	80.6	93.1
49.75	109.9	83.1	96.5
50.75	119.9	86.0	103.0
51.75	123.5	79.4	101.5
53.00	120.6	74.8	97.7
54.00	130.1	84.3	107.2
55.00	121.6	74.1	97.8
56.00	127.6	80.0	103.8
57.00	125.7	78.1	101.9
58.00	122.4	74.9	98.7
59.00	125.0	77.5	101.2
60.00	126.8	79.2	103.0

AVERAGE CORRECTED WARBURG DATA  
 SAMPLES AVERAGED- IITRICCE+NA AC

DATE-JAN 2, 1979

FLASK NOS.16/\*\*

TEST TIME (HRS)	FLASK 16 UPTAKE SUM (UL)	FLASK*** UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	-1.0	0.0	-1.0
2.00	-1.4	0.0	-1.4
3.00	5.0	0.0	5.0
4.00	3.1	0.0	3.1
5.00	4.8	0.0	4.8
6.00	3.9	0.0	3.9
7.00	3.0	0.0	3.0
8.00	3.9	0.0	3.9
9.00	-1.3	0.0	-1.3
10.00	-1.2	0.0	-1.2
11.00	.4	0.0	.4
12.00	4.6	0.0	4.6
13.00	.2	0.0	.2
14.00	-2.5	0.0	-2.5
15.00	.1	0.0	.1
16.00	-1.5	0.0	-1.5
17.00	-1.7	0.0	-1.7
18.00	1.1	0.0	1.1
19.00	9.7	0.0	9.7
20.00	10.5	0.0	10.5
21.00	15.8	0.0	15.8
22.25	27.3	0.0	27.3
23.50	50.4	0.0	50.4
24.50	70.1	0.0	70.1
25.50	96.4	0.0	96.4
26.50	133.5	0.0	133.5
27.50	143.1	0.0	143.1
28.50	148.4	0.0	148.4
29.50	151.9	0.0	151.9
30.50	150.1	0.0	150.1
31.50	162.6	0.0	162.6
32.75	164.4	0.0	164.4
33.75	170.5	0.0	170.5
34.75	168.6	0.0	168.6
35.75	176.4	0.0	176.4
36.75	181.0	0.0	181.0
37.75	179.2	0.0	179.2
38.75	187.9	0.0	187.9
39.75	188.0	0.0	188.0
40.75	195.1	0.0	195.1
41.75	194.2	0.0	194.2
42.75	184.8	0.0	184.8
43.75	195.2	0.0	195.2
44.75	143.2	0.0	143.2
45.75	202.8	0.0	202.8
46.75	211.6	0.0	211.6
47.75	213.4	0.0	213.4
48.75	217.0	0.0	217.0
49.75	221.5	0.0	221.5
50.75	228.3	0.0	228.3
51.75	228.4	0.0	228.4
53.00	232.8	0.0	232.8
54.00	247.6	0.0	247.6
55.00	240.7	0.0	240.7
56.00	248.6	0.0	248.6
57.00	245.0	0.0	245.0
58.00	241.6	0.0	241.6
59.00	247.7	0.0	247.7
60.00	249.5	0.0	249.5

# AVERAGE CORRECTED WARHUNG DATA

SAMPLES AVERAGED- IITRI  
IITRI

DATE-JAN 2, 1979

FLASK NOS. 4/ 5

TEST TIME (HRS)	FLASK 4 UPTAKE SUM (UL)	FLASK 5 UPTAKE SUM (UL)	AVERAGE UPTAKE SUM (UL)
0.00	0.0	0.0	0.0
1.00	-5.3	-5.3	-5.3
2.00	-4.4	-2.7	-3.6
3.00	4.8	6.7	5.7
4.00	1.1	-5.5	-3.3
5.00	4.5	1.2	2.8
6.00	-0.0	-1.5	-0.8
7.00	-1.9	-0.6	-1.8
8.00	1.7	0.2	0.9
9.00	-3.4	-1.4	-2.4
10.00	-15.4	-20.6	-18.0
11.00	-3.6	-3.3	-3.5
12.00	-2.9	-4.3	-3.6
13.00	-5.7	-7.1	-6.4
14.00	-4.8	-6.2	-5.5
15.00	-5.8	-8.8	-7.3
16.00	-13.2	-11.2	-12.2
17.00	-7.6	-10.7	-9.1
18.00	-11.8	-15.0	-13.4
19.00	-12.1	-15.2	-13.6
20.00	-6.1	-7.3	-6.7
21.00	-6.1	-7.3	-6.7
22.25	7.0	-4.6	1.2
23.50	13.0	1.4	7.2
24.50	17.7	6.3	12.0
25.50	24.6	13.3	18.9
26.50	31.6	20.4	26.0
27.50	39.4	26.5	32.9
28.50	42.8	30.0	36.4
29.50	48.0	33.5	40.7
30.50	54.8	38.7	46.7
31.50	67.2	47.6	57.4
32.75	72.5	51.2	61.8
33.75	87.0	57.2	72.1
34.75	83.3	60.5	71.9
35.75	87.6	64.8	76.2
36.75	90.5	65.9	78.2
37.75	93.7	67.5	80.6
38.75	97.2	71.0	84.1
39.75	98.9	76.3	87.6
40.75	99.1	72.9	86.0
41.75	99.8	73.7	86.8
42.75	94.0	69.6	81.8
43.75	100.9	78.2	89.5
44.75	109.2	81.4	95.3
45.75	111.7	85.8	98.8
46.75	115.1	89.2	102.2
47.75	115.2	87.6	101.4
48.75	120.4	91.1	105.8
49.75	119.6	92.1	105.8
50.75	129.7	97.0	113.4
51.75	131.5	100.7	116.1
53.00	137.4	106.7	122.1
54.00	146.9	114.5	130.7
55.00	148.7	114.6	131.6
56.00	156.5	120.7	138.6
57.00	165.0	127.6	146.3
58.00	161.7	124.2	143.0
59.00	164.3	126.8	145.6
60.00	166.0	125.1	145.6

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